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Advances of Nanotechnology in Eradication Bacterial Infectious Diseases: A Recent Review.

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Abstract

Many antibiotics have proven ineffective due to the increase of multiple drug resistance problems among pathogenic bacteria in the community or hospitals. Consequently, there is an urgent need to find effective materials to inhibit the activity of multi-drug resistant (MDR) bacteria. Therefore, this issue was presented in this study as a problem in urgent need of a solution, including finding alternatives to antibiotics. Hence, the present review aims initially to illustrate nanotechnology and its various medical applications and show its role in infectious diseases, therefore, it presents nanoparticles and the possibility of using them as alternatives to ineffective antibiotics against some mortal pathogens. Thus, the review shows the nanoparticles and their exceptional chemical and physical characteristics of nanoparticles, including the easiest of manufacture, low cost, and time and effort saving, and shows their promising benefits in many biological and medical applications, including antibacterial, antifungal, and anticancer. In addition, the study reviews the potential of using nanoparticles in future clinical trials. Finally, it shows the obstacles to using nanoparticles, thus, emphasizing the need to study the toxicological effects of nanoparticles before applying them in clinical settings.

1. Introduction:

Nanotechnology is the study of and creation of new technologies at the molecular and atomic levels, or roughly 1–100 nm, or a billionth (10^{-9}) of a metre [1]. It is used to understand the basics of phenomena to create structures, systems, and devices at the nanoscale with multiple functions. In the eighties, when the scanning electron microscope was developed, it was the main reason for the launch of nanotechnology. Four disciplines are included in nanotechnology: chemistry, physics, engineering, and biology. These disciplines must be combined to create an advanced science. For this reason, this technology is able to create many devices in the fields of medicine, biological materials, and energy production [2], [3]. As such, nanotechnology is a collaborative field. In 1974, Professor Norio Tainguchi at the Tokyo University of Science, during his research paper, defined nanotechnology as processed materials that separate and arrange through an atom or a single molecule [4]. There are many applications of nanotechnology in various fields of science, including organic chemistry, molecular biology, semiconductor physics, and so on. Therefore, scientists discuss the future effects of nanotechnology. Many countries have invested billions of dollars in this technology because they believe it will be crucial for the future. The United States, for example, invested $3.7 billion throughout its effort, followed by Japan ($750 million) and the European Union ($1.2 billion) [5]. Nanotechnology offers a broad spectrum of applications [6], [7]:

1. Medicine and health.
2. Energy and environment.
3. Transport.
4. Electronic Engineering.
5. Space Exploration.
6. Food.

1.1 Applications of Nanotechnology in the Medical Field:

The applications of nanotechnology in the medical field are called nanomedicine. These applications are considered the most important potential applications of nanotechnology, which include:

1. Biological labels [8], [9].
2. Gene and drug delivery [10].
3. Protein detection [11].
4. DNA structural investigation [12], [13].
5. Tissue engineering [14].
6. Thermal cancer therapy (hyperthermia) [15], [16].
7. Pathogen detection [17].

1.2 Nanomedicine:

Nanomedicine has gained great interest in medical settings due to the wide range of possible applications it can offer. Nanomedicine applications concern biological tags, protein/DNA analysis, gene/drug delivery systems, pathogenic detection possibilities, disease diagnosis tools, tissue engineering, photothermal cancer therapy, enhancement of imaging, and toxicity examinations. In the future, there is no doubt about using nanomedicine in different medical fields, where, with the aid of nanomedicine, it becomes possible for early diagnosis and efficient detection of diseases, improving medical strategies, choosing the accurate treatment, and command of disease [18], [19].

There are many examples of using nanotechnology in the medical field. For instance, nanosensors with advanced features can be developed to diagnose cancer. This technique made an excellent contribution to this field through scientific research on stem cells. Targeting and treating stem cells has been accomplished using magnetic nanoparticles (MNPs) [20]. Quantum capture imaging was also used to track stem cells and deliver genes/ drugs to them [21]. In addition to the use of materials and structures at the nanoscale, such as carbon nanotubes, fluorescent metal nanoparticles (MNPs) [22], and Nanoluster (NCs), to enhance stem cell treatment [23]. In particular, one of nanotechnology applications in medical field is extremely diagnose and treat of pathogenic bacteria [24]. In addition, using selenium nanoparticles to inhibits pathogenic bacteria [19].

This review, aimed to present the potential applications of nanotechnology nanoparticles in the field of medicine especially those that focus on infectious diseases and the possibility of treating them without developing of resistance issues. It is, therefore, a good approach to gather most of the available knowledge regarding nanoparticles and their possibilities in biological and medical applications which in turn produce a scientific platform for other researchers.

2. Pathogenic Bacterial Infections:

Bacterial infections are diseases that are caused by bacteria and affect different organs and tissues of the body, such as the skin, vagina, respiratory tract, and brain [25]. Bacteria are single-celled organisms that can be found everywhere and spread to cause various infections, and some have the ability to multiply or release toxins in the human body. Bacteria are often treated with antibiotics; however, some can resist most of the locally available antibiotics, which leads to the generation of multidrug-resistant bacteria. Biological sources, including bacteria, viruses, parasites, and fungi cause different infection conditions such as tetanus, respiratory infections and food poisoning that threaten people's health [26] The medical institutes offer resources and knowledge for monitoring and managing biological dangers that can spread via food, the air, or the water. As known some bacteria have benefits; for instance, intestine bacteria provide essential nutrients such as vitamin K [27]. However, small intestinal bacterial overgrowth may cause non-alcoholic state hepatitis, small bowel movement decreases, causing overgrowth, but antibacterial therapy can reduce the severity of non-alcoholic state hepatitis [28]. In addition to that, bacteria can spread via a variety of pathways, and they need a sufficient number of remaining organisms to assault their host in order to do so. Numerous bacteria have evolved to live in food, water, and soil. Some of these bacteria also infect animals and insects, which is how they spread to humans.

2.1 Factors Leading to the Development of Infection:

The emergence of bacterial infections can be caused by a variety of factors [29].

1. Types of pathogens that cause infection.
2. Pathogenicity, which is the possibility of the organism in generate the disease.
3. The mechanism of the protection system of the body.

4. Genetic composition and nutritional status.

5. Age and exposure of the organism to contamination.

2.2 Pathogenic Bacterial Infections:

Bacteria can result in various types of infections. For instance, food contamination by bacteria is the cause of many different gastrointestinal illnesses. The majority of the time, bacterial toxins are what cause illness signs and symptoms. The cells lining the gastrointestinal tract, usually the colon, are harmed by the toxins. This results in the typical diarrheal or watery stool symptoms. These infections include Staphylococcal Food Poisoning, Shigellosis (Bacillary Dysentery), Salmonellosis, Typhoid Fever, and E. coli infections [30]. In addition, there are two categories of respiratory bacterial infections: upper respiratory tract infections (URI), which include tonsillitis, laryngitis, acute rhinitis, acute rhinosinusitis, and acute otitis media. The second category consists of more serious infections than URT, such as lower respiratory tract infections (LRI), which include tracheal, pneumonia, bronchiolitis, and acute bronchitis [31]. Vaginal Bacterial infections are one of the most common forms of bacterial vaginosis arise from an imbalance in the number of vaginal bacterial populations. Some types of bacteria are anaerobic and negative, such as peptosteptococcus [32]. Furthermore, bacterial skin infections, such as boils and carbuncles, are common in public and clinical settings [33]. There is a high prevalence of purulent skin infections caused by methicillin-resistant Staphylococcus aureus (MRSA) [34]. Bacteria also can be isolated from patients with Cholecystitis [35].

2.3 Examples of Pathogenic Bacteria:

There are many examples on pathogenic bacteria, Clostridium tetani is obligatory anaerobic bacteria, capable of producing internal spores that have an effect on humans. It causes tetanus as the most widespread disease. This bacterium secretes tetanus toxin in a lethal dose for humanity [36]. Klebsiella pneumonia is non-motile, fermentative facultative anaerobic gram-negative bacteria. It causes pneumonia and sometimes stimulate urinary tract infections or cause underlying diseases such as cirrhosis of the liver and biliary tract, bone tumours, bacteraemia, and alcoholism, as well as it has also been isolated from the lungs of patients. [37]. In addition, Pseudomonas aeruginosa is a gram-negative bacterium that typically considered an opportunistic disease occurs among individuals who have altered host defence mechanisms, and these need only new means [38]. Salmonella typhi is a gram-negative bacteria and facultative anaerobic that can cause systemic infections and typhoid fever, in addition to causing gastroenteritis [39]. Staphylococcus aureus is a common component of the body's microbiota and a member of the Bacillota. It is often found on the skin and in the upper respiratory system [40]. It can grow without oxygen and frequently exhibits positive results for catalase and nitrate reduction [26].

2.4 Antibiotic Role in Bacterial Suppressing:

Instead of acting on the host cells, the optimal antibacterial agent targets a specific location within the sick organism. Due to their differences from human cells, they can target four primary locations within the cell. The cell wall, cell membrane, synthetic pathway, DNA, and ribosomes. Antibiotics and treatments are often biological or chemical substances. Three classification schemes exist for the antibacterial agent: In accordance with whether it was bactericidal, i.e., killing it or preventing its growth 2. Through chemical composition 3. Through the target site, the emergent issue of antibiotic resistance among most pathogenic bacterial strains led to reducing the impacts of these drugs which in turn created a real need for new antibiotics [41].

2.5 The Problem of Antibacterial Resistance:

Antibiotics are considered the most important category for pharmaceutical and medical preparations, and it cannot be denied that antibiotic was a blessing for human society in the fight against bacteria. Despite that, the bacteria developed and became innately resistant to certain categories of antibiotics, either because by losing the target andimpermeable to the drug [42].

Bacteria developed resistance by one of the various mechanisms, where the resistant strains of bacteria have selective advantages as they can live in the presence of antibiotics and other factors. This phenomenon is considered important when the use of antibiotics is common, as in hospitals and among residents. Some resistance genes are carried on the plasmid and independently replicate DNA molecules outside their chromosome and thus can be transferred to bacteria of other species [43].

According to Dowell et al., 1998, the main three mechanisms of resistance are: 1) altering the target location; 2) generating enzymes that impede the activity of antibiotics; and 3) altering the target site while contrast or pumping antibodies out of the cell [44].

When a person takes an antibiotic, his whole body is exposed to the drug and not only the organism that caused the infection is lost. Since the use of these antibiotics is associated with the emergence of resistance, prudent usage, rather than overuse, is the primary strategy to address the issue of antibiotic resistance. The use of antibacterial agents in viral infections or infections that clear up on their own without treatment is an example of incorrect use, as is the ingestion of broad-spectrum antibiotics, which block or kill multiple organisms at once when the spectrum agent is narrow [45].

The most important topic in this research is using nanomaterials and nanoparticles as alternatives to antibiotics for pathogenic bacteria, thus solving the continuously increased

antibiotic resistance problem. Antibiotic resistance issues can be solved using nanoparticles in combination with drugs or nanoparticles alone. Zinc oxide nanoparticles, for instance, have the power to lower antibiotic resistance and improve the antibacterial activity of ciprofloxacin against microorganisms by interfering with various proteins that interact with antibiotic resistance or pharmacological mechanisms [46].

2.6 Nanoparticles:

Nanomaterials are materials that have arrangements at the nanoscale dimensions with a range of 1-100 nanometres [47]. Nanomaterials can differ from their bulk-form counterparts in a variety of physical and chemical ways [48]. Nanomaterials have many medical uses and have new potential in science and technology due to their effective interaction with biological molecules. Moreover, nanomaterials can be utilised to improve the pharmacological and therapeutic effects of drugs due to their large surface-to-volume ratio, in turn, they can bind to cancer cells [49].

In the healthcare industry, it is possible to understand the interactions of nanoscale devices with biomolecules, whether inside or outside human cells, by studying their interaction and investigating the physical properties of nanomaterials within biological materials [50]. For example, nanofilters are good candidates for adjuvants to the vaccine and include beneficial features such as increasing the interaction of drug molecules with epithelial cells, which leads to maximum absorption of the drug molecule [51], [52]. Nanoparticles are small-sized particles that have physical and chemical properties that are noticeably different from those of their larger counterparts in materials. Because of their incredibly small size, nanoparticles are employed to deliver specific medications to a targeted location. The selective delivery approach can reduce the pain of patients and the side effects of drug accumulation. Nanoparticles used to deliver molecules and drugs can improve the bioavailability of a drug in specific locations of the body over a period of time [53].

2.7 Methods of Synthesis Nanoparticles:

There are three methods for manufacturing nanoparticles [54] Figure 1:

1. Biological methods: They are considered one of the simplest, easiest and cheapest methods, and it is environmentally friendly. That is why it is known as green methods, which is one of the "bottom-up" manufacturing methods Figure **??**. the "bottom-up" manufacturing method involves fabricating materials starting at the atomic level that are built up to make small materials that are arranged in specific structures at the nanoscale (1-100 nm). This approach has received considerable attraction in the green synthesis of nanoparticles [55], [56]. Green methods of nanoparticle synthesis have developed into an important branch of nanotechnology.

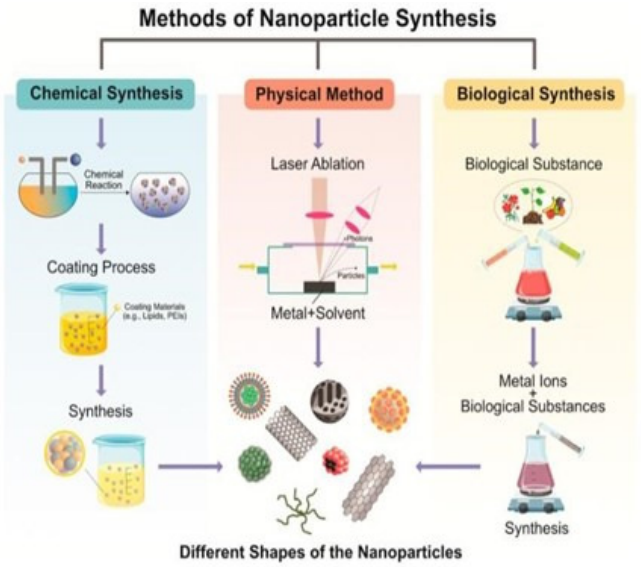

Figure 1. Methods of nanoparticle synthesis [58].

Microorganisms such as bacteria, fungi, yeasts and algae, as well as various parts of plants, can be used on a wider scale to prepare various nanomaterials.

2. Chemical methods: Chemical methods show a variety of bottom-up synthesis techniques. They are used to obtain controlled pure particle size and shape depending on the size and type of material and the characteristics of the method. Whether in the liquid or gaseous phase, larger nanoparticles are formed through the chemical assembly of smaller ions. The appropriate method depends on the size and type of nanomaterial, the ease of the method, and the properties of the nanocomposite required. Among the most important chemical manufacturing methods are: for example, the Sol–gel method, co-precipitation method, and colloidal methods.

3. Physical methods: In these methods, the larger materials are crushed into smaller particles using mechanical grinding technology in the "top-down" approach that seeks to create small materials using larger ones and includes fabricating structures by processing them on the nanoscale [55], [57] Figure **??**. The main disadvantage of this method is the efficiency of obtaining the desired and homogeneous size and shape of the particles produced. Among the most important physical methods are laser ablation and vaporization, RF plasma, and thermal decomposition methods.

2.8 Types of Nanoparticles:

Several types of nanoparticles have been developed on the basis of unique physical properties, especially in the field of biotechnology. These particles have certain properties that

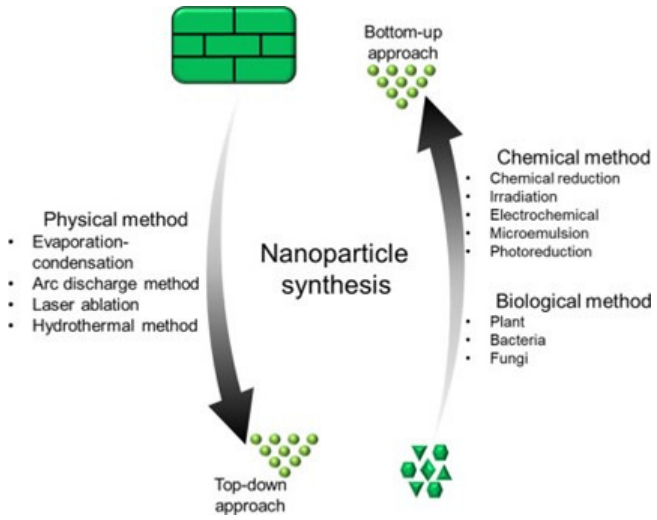

Figure 2. The approaches for nanoparticle synthesis [55].

include optical, magnetic, electronic, and catalytic properties [59].

1. Organic nanoparticles

   There are organic nanoparticles (NPs) in the natural world. The majority of organic NPs consist of several chemical or polymeric components. Furthermore, organic NPs, such as micelles or vesicles, are dynamic entities that can alter in size and shape over time. They can also load molecules through physical encapsulation, conjugation on the surface, or in the core. These properties make them attractive systems for delivering molecules, particularly for drug delivery and biomedical applications [60].

2. Inorganic nanoparticles

   Because of their inherent antibacterial qualities, metal and metal oxide nanoparticles (NPs) have shown enhanced efficacy both as nanobiocides and as nanocarriers for antimicrobial medications. Due to their established antibacterial mechanisms and bio/cytocompatibi
   -
   lity, gold, silver, copper, zinc oxide, titanium oxide, magnesium oxide, and iron oxide nanoparticles are more dominant among them. Moreover, the incorporation or attachment of inorganic nanoparticles to organic or inorganic films expands their potential uses in implant or catheter coatings as well as wound dressings [61].

3. Polymeric nanoparticles

   Particles known as polymeric nanoparticles (NPs) have the ability to include active substances that are either surface-adsorbed onto the polymeric core or trapped within it. The targeted delivery of medications for the treatment of many diseases has demonstrated significant promise with polymeric nanoparticles. It has also made tremendous progress within the field of research where the dispersion of preformed polymers and the polymerization of monomers are two powerful strategies in medical settings [4].

2.9 Different Types of Metal Nanoparticles:

2.9.1 Gold nanoparticles (AuNPs):

Gold nanoparticles are considered to have intrinsic antimicrobial properties and allow for a strong particle function. Researchers have looked into treating bacterial biofilms with gold NPs to treat biofilms [62]. AuNPs are biologically synthesized by reducing gold salts via several methods including the use of plant extracts [63], and chemically using a reducing agents such as sodium borohydrate (NaBH4) [64]. AuNPs showed inhibition of 90% of S. aureus biofilm bacteria, their disruption by 95%, and their cell membranes by 40%, as they exceeded the performance of silver particles when they were selected in terms of inhibition [65].

2.9.2 Iron Nanoparticles:

Because of their many uses, magnetic nanoparticles have been thoroughly investigated for usage in the biomedical industry. Temperature-based therapeutics, targeted medication administration, and magnetic resonance imaging (MRI) may all be made easier by iron nanoparticles. Magnetic nanoparticles (NPs) can be synthesized via thermal breakdown or co-precipitation, and they are affordable and biocompatible. The co-precipitation approach forms a black substance of iron deposit of nanoparticles by adding a base to an aqueous combination of Fe+3 and Fe+2 salts at room temperature or raised in an oxygen-free environment. Many other investigations indicate the successful eco-friendly synthesis of magnetic iron nanoparticles [66]. A study revealed that the biogenic -Fe2O3 showed antimicrobial activity against three types of bacteria, Staphylococcus aureus, Listeria monocytogenes and Escherichia coli [67].

2.9.3 Zinc Oxide Nanoparticles:

It is considered one of the important molecules whose structural and optical properties have been studied, their performance on solar cells has been studied, and their efficiency has been compared. These nanoparticles are synthesised through a simple deposition method and aged at different times as photospheres for solar cells [68]. Zinc oxide nanoparticles were synthesised by many approaches, chemical [69], and biological. They exhibit antibacterial effects against different pathogens that cause urinary tract infections such as Bacillus subtilis, E. coli, Streptococcus sp. and Serratia sp. [70].

2.9.4 Silica Nanoparticles:

Silica nanoparticles are one of the most important particles that provide biodegradable materials and act as delivery for different antimicrobial agents to biofilms in a useful way. In

addition, these materials revealed their ability to release active factor particles attached or encapsulated upon contact with water. Silica NPs Figure 6 , are often combined with nitric oxide that act as a vector to deliver donor biomolecules. As an endogenous free radical, nitric oxide (NO) is involved in numerous biological processes [71].

2.9.5 Silver Nanoparticles:

Since ancient times, silver's antibacterial properties have been known. Researchers started to become interested in silver's antibacterial properties due to growing concern about antibiotic resistance to bacterial infections and biofilms [72]. According to Murphy et al., silver functions as a broad-spectrum antiseptic and is efficient against both gram-positive and gram-negative bacteria, fungi, and viruses [73]. Silver nanoparticles can be prepared in several ways, the most popular chemical approach is reducing Ag+ to Ag0 by using a reducing agent such as sodium borohydride in the presence of a stabilizer to keep the AgNPs from aggregation [74]. The environmentally friendly methods for silver nanoparticle synthesis include the use of plant extracts [75]. For example, using the extract of Silybum marianum fruit to synthesise of AgNPs (25nm) [76]. Furthermore, a study by Neethu, et al., (2018) revealed using fungi for the biosynthesis of AgNPs [77].

2.9.6 Copper Nanoparticles:

Copper nanoparticles show many properties as being antimicrobial, in addition, are less expensive than other metals like silver and gold. A wide range of synthesis methods provides flexibility and the facility to produce copper nanoparticles [78]. There are several uses for copper particles as coating agents on biomedical devices to control the spread of infections [79].

2.10 Applications of Nanoparticles:

The small size of nanoparticles offers great benefits in oncology, especially in producing outstanding images of the tumor site through the combination of magnetic resonance imaging and light emission. In addition, nanoparticles have a high surface area relative to their small size, which allows the different functional groups to attach to the nanoparticles, in turn binding to specific tumor cells [80].

One of the nanoparticles' applications is the photodynamic treatment of cancer, where the nanoparticle is penetrated into the tumour and then exposed to the optic light from the outside. The nanoparticle is heated due to the energy of the light when it absorbs this light, and the heat destroys cancer cells [81]. Some nanoscale particles are used as labels or markers for biological materials such as DNA, antibodies, and tumour cells; thus, the diagnosis has become more flexible and sensitive [82]. In addition, gene sequencing has become more efficient with the invention of nanodevices [83]. Moreover, tissue engineering is developed through the application of nanotechnology using appropriate growth factors with nanomaterials, so with the help of nanotechnology, it becomes easy

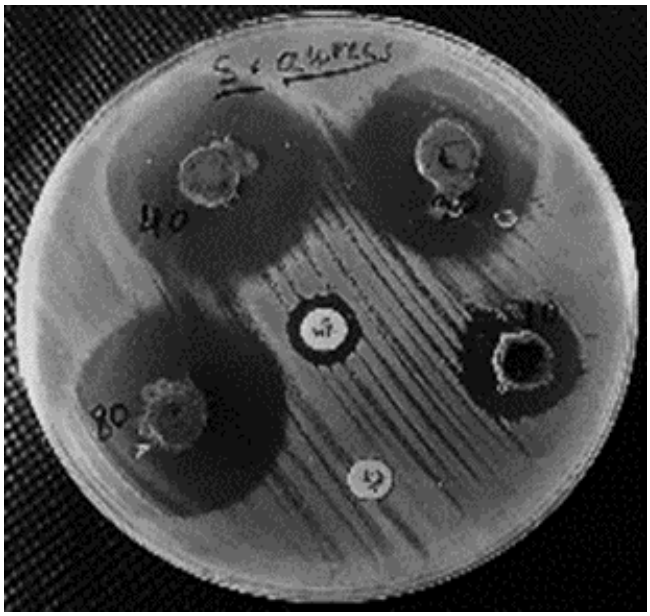

Figure 3. The Disk diffusion method for in vitro evaluation of nanoparticle activity on Staphylococcus aureus [19].

to reproduce or modify damaged tissues [14]. The immune response is one of the most important subjects that developed using nanoparticles. Further, nanoparticles become now new alternatives to antibiotics [84].

2.11 In Vitro Evaluation of the Antibacterial Activity of Nanoparticles:

The antibacterial activity of nanoparticles can be tested using different methods:

2.11.1 The Disk Diffusion Method:

In this method, the study of the results and their impact is done by spreading the bacterial suspension on a nutrient agar plate and then adding discs saturated with nanoparticles. The results are recorded by calculating the inhibition zone and comparing it with the references Figure 3 [19]. Nanoparticles were used as antibacterial agents in many researchers. A study by Radhi and co-workers, (2023) indicated that a well diffusion method using a Petri dish showed considerable inhibition zones of Staphylococcus aureus-multi drug resistant (MDR) bacteria-around wells filled with nanoparticles compared to wells of plant extracts.

2.11.2 Method of Bacterial Liquid Medium:

Nanoparticles have a higher absorption than other solutions, which means they offer an different biological and medical uses Figure 4 [85]. Using silver nanoparticles against MRSA bacteria is one example of this test. The minimal inhibitory concentration was assessed using various concentrations of nanoparticles cultured in bacterial culture (MIC) By measuring the optical density at 625 nm [86].

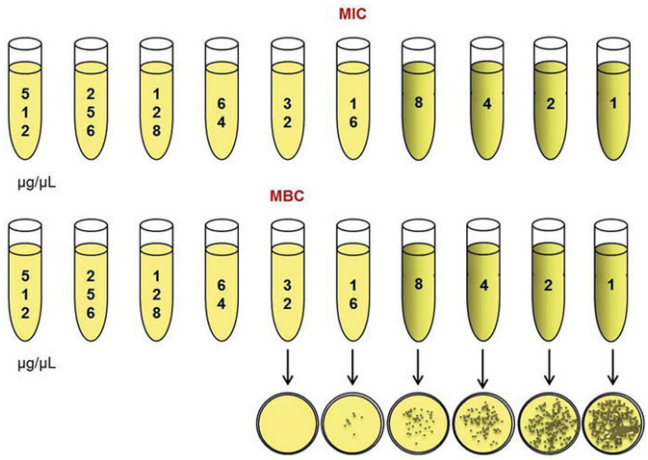

Figure 4. Evaluation of nanoparticle activity using the dilution method of bacterial liquid medium [85].

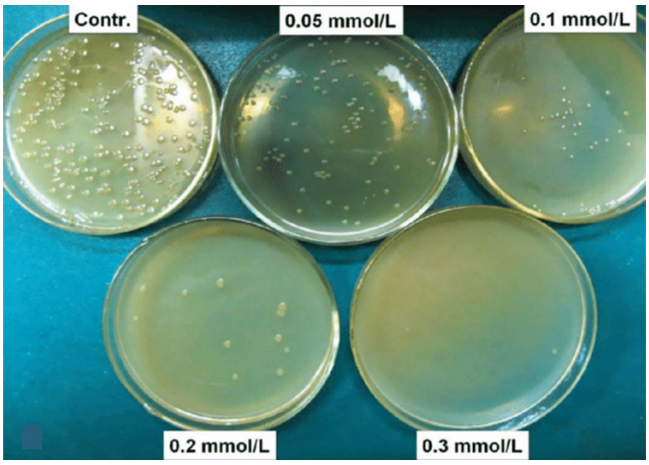

Figure 5. Colonies method for in vitro evaluation of nanoparticle activity [86].

2.11.3 Colonies Method:

The evaluation of nanoparticles' effect on bacteria can be done by testing the ability of one bacterial cell to grow and produce a colony. In this case, the number of colonies in the tested dishes compared to the control can be used to evaluate nanoparticles' efficiency in killing bacteria Figure 5 [86].

2.12 In Vivo Evaluation of Nanoparticles as Antibacterial:

Using a variety of animal models is essential for scientific investigation into the origins, progression, and management of the disease; mice are the most frequently utilized model in this regard. Nanotechnology can change the face of medical implants and their services in the human body to treat and repair damaged cells with nanomaterials due to the properties of these materials. Nanoparticles are injected into the bodies of mice from some places, such as the tail. Nanoparticles can easily pass through the bloodstream to any organ and detect or

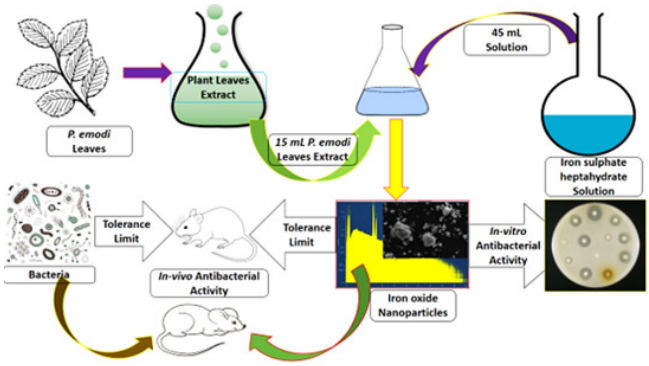

Figure 6. In vivo evaluation of nanoparticles as antibacterial [88].

treat pathogens Figure 6. Despite these advantages, nanotechnology applications have risks and negative consequences for the human body due to the toxicity of these materials [87].

2.13 Obstacles of Nanoparticles Use in Vivo (Cytotoxicity):

The cytotoxicity of nanoparticles is defined as the degree to which a nanoparticle's interaction with a cell can disturb cellular structures or functions essential for cell survival and growth. The toxicity test is a quick and easy approach for conducting initial assessments of nanoparticle toxicity [89], [90] The properties of nanoparticles that affect toxicity, including the physical properties that make nanoparticles more toxic than others, can contribute to toxicity, as the smaller size has more surface area to interact with cellular components such as nucleic acids, proteins, and others [89].

3. Conclusion:

Drug resistance issue by bacteria indeed complicates the diagnosis and treatment of bacterial infectious conditions. The majority of medications utilized nowadays to treat infectious diseases are not selective and deliver some toxicity. However, nanoparticles show promising interactions with biomolecules inside and on the surface of cells as well as showing good cellular uptake. The researchers have used the exceptional cellular linkage of nanoparticles to produce medicines to treat various ailments, including infectious diseases. The capacity of nanoparticles to produce reactive oxygen species that cause damage to the pathogen's cell wall, and/ or their ability to bind to the DNA or the RNA of pathogens, are thought to be responsible for their antibacterial/ antifungal activity. In addition, the combination of antibacterial medicines and nanoparticles leads to good synergistic effects. Thus, Nanoparticles are required to proceed to clinical studies. The toxicological implications of nanoparticles must also be considered when using nanoparticles, besides their feasible therapeutic benefits.

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Declarations:
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تطورات تكنولوجيا النانو في القضاء على الأمراض المعدية البكتيرية: مراجعة حديثة

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الخلاصة

أثبتت العديد من المضادات الحيوية عدم فعاليتها بسبب زيادة مشاكل مقاومة الأدوية المتعددة بين البكتيريا المسببة للأمراض في المجتمع أو المستشفيات. وبالتالي، هناك حاجة ملحة لإيجاد مواد فعالة لمنع نشاط البكتيريا المقاومة للأدوية المتعددة ولذلك تم طرح هذه القضية في هذه الدراسة كمشكلة بحاجة ماسة إلى حل، بما في ذلك إيجاد بدائل للمضادات الحيوية. ومن هنا تهدف هذه المراجعة مبدئياً إلى توضيح تقنية النانو وتطبيقاتها الطبية المختلفة وإظهار دورها في الأمراض المعدية، لذا فهي تعرض الجسيمات النانوية وإمكانية استخدامها كبدائل للمضادات الحيوية غير الفعالة ضد بعض مسببات الأمراض القاتلة. وهكذا، توضح المراجعة الجسيمات النانوية وخصائصها الكيميائية والفيزيائية الاستثنائية بما في ذلك سهولة التصنيع، وانخفاض التكلفة، وتوفير الوقت والجهد، وتبين فوائدها الواعدة في العديد من التطبيقات البيولوجية والطبية، بما في ذلك مضادات البكتيريا والفطريات ومضادات السرطان. بالإضافة إلى ذلك، تستعرض الدراسة إمكانية استخدام الجسيمات النانوية في التجارب السريرية المستقبلية. وأخيراً، توضح معوقات استخدام الجسيمات النانوية، وبالتالي التأكيد على ضرورة دراسة التأثيرات السمية للجسيمات النانوية قبل تطبيقها في البيئات السريرية.

الكلمات الدالة: تقنية النانو؛ الجسيمات النانوية؛ البكتريا المقاومة للأدوية المتعددة؛ الامراض المعدية.

التمويل: لايوجد.

بيان توفر البيانات: جميع البيانات الداعمة لنتائج الدراسة المقدمة يمكن طلبها من المؤلف المسؤول.

اقرارات:

تضارب المصالح: يقر المؤلفون أنه ليس لديهم تضارب في المصالح.

الموافقة الأخلاقية: لم يتم نشر المخطوطة أو تقديمها لمجلة أخرى، كما أنها ليست قيد المراجعة.